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OPHIUCHUS 1622−2405: NOT A PLANETARY-MASS BINARY[1]

K. L. Luhman,[2] K. N. Allers,[3,4] D. T. Jaffe,[5] M. C. Cushing,[4,6,7] K. A. Williams,[6,8]
C. L. Slesnick,[9] and W. D. Vacca[10]
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ABSTRACT

We present an analysis of the mass and age of the young low-mass binary Oph 1622−2405. Using resolved optical spectroscopy of the binary, we measure spectral types of M7.25 ± 0.25 and M8.75 ± 0.25 for the A and B components, respectively. We show that our spectra are inconsistent with the spectral types of M9 and M9.5-L0 from Jayawardhana & Ivanov and M9 ± 0.5 and M9.5 ± 0.5 from Close and coworkers. Based on our spectral types and the theoretical evolutionary models of Chabrier and Baraffe, we estimate masses of ~0.055 and ~0.019 $M_\odot$ for Oph 1622−2405A and B, which are significantly higher than the values of 0.013 and 0.007 $M_\odot$ derived by Jayawardhana & Ivanov and above the range of masses observed for extrasolar planets ($M \lesssim 0.015\ M_\odot$). Planet-like mass estimates are further contradicted by our demonstration that Oph 1622−2405A is only slightly later (by 0.5 subclass) than the composite of the young eclipsing binary brown dwarf 2M 0535-0546, whose components have dynamical masses of 0.034 and 0.054 $M_\odot$. To constrain the age of Oph 1622−2405, we compare the strengths of gravity-sensitive absorption lines in optical and near-infrared spectra of the primary to lines in field dwarfs ($\tau > 1$ Gyr) and members of Taurus ($\tau \sim 1$ Myr) and Upper Scorpius ($\tau \sim 5$ Myr). The line strengths for Oph 1622−2405A are inconsistent with membership in Ophiuchus ($\tau < 1$ Myr) and instead indicate an age similar to that of Upper Sco, which is in agreement with a similar analysis performed by Close and coworkers. We conclude that Oph 1622−2405 is part of an older population in Sco-Cen, perhaps Upper Sco itself.

Subject headings: binaries: visual — infrared: stars — stars: evolution — stars: formation — stars: low-mass, brown dwarfs — stars: pre–main-sequence

1. INTRODUCTION

Since the discovery of the first free-floating brown dwarfs a decade ago (Stauffer et al. 1994; Rebolo et al. 1995; Basri et al. 1996), surveys of young clusters and the field have found brown dwarfs in increasing numbers and at decreasing masses. A natural consequence of these growing samples of brown dwarfs has been the identification of binary systems with progressively lower total masses (Chauvin et al. 2004; Burgasser et al. 2006 and references therein). The least massive binaries are potentially valuable for testing theories for the formation of objects at the bottom of the initial mass function (Burgasser et al. 2006; Luhman et al. 2006). To produce meaningful results, these tests require reliable measurements of the basic properties of the components of substellar binaries, including spectral type, luminosity, age, and mass.

Oph 1622−2405 is one such low-mass binary that deserves careful scrutiny. This system was discovered during a search for disk-bearing young brown dwarfs with the *Spitzer Space Telescope* (Allers 2005; Allers et al. 2006). The 1.9″ pair was only partially resolved by *Spitzer*, but was fully resolved in optical and near-infrared (IR) images and low-resolution near-IR spectroscopy presented by Allers (2005) (see also Allers et al. 2007). Through this spectroscopy, she classified each component as a pre–main-sequence object and measured spectral types of M7.5 and M8 for the primary and secondary, respectively. By placing the two components on the Hertzsprung-Russell (H-R) diagram with theoretical evolutionary models, Allers (2005) estimated masses of 0.06 and 0.05 $M_\odot$ and a system age of ~40 Myr. In comparison, Jayawardhana & Ivanov (2006a, 2006b) have reported spectral types of M9 and M9.5-L0 and masses of 0.013 and 0.007 $M_\odot$ for the components of Oph 1622−2405, leading Jayawardhana & Ivanov (2006b) to characterize Oph 1622−2405 as the first known planetary-mass binary. Close et al. (2007) independently discovered the binarity of Oph 1622−2405 and estimated masses of 0.017 and 0.014 $M_\odot$ for its components.

We seek to better determine the physical properties of the components of Oph 1622−2405, particularly their masses, through new optical and near-IR spectroscopy (§ 2). With the optical data, we measure the spectral types of Oph 1622−2405A and B with the optical classification scheme that has been most commonly applied to young late-type objects and show how these types compare to those of other young binaries through direct comparison of their optical spectra (§ 3.1). We use gravity-sensitive absorption lines in the optical and IR spectra of Oph 1622−2405A to constrain its age (§ 3.2). We then estimate the masses of Oph 1622−2405A and B via theoretical evolutionary models and by considering the dynamical mass measurements of the eclipsing binary brown dwarf 2MASS J05352184−0546085 (hereafter 2M 0535-0546; § 3.4).

2. OBSERVATIONS

The optical and IR images of Oph 1622−2405A and B from Allers (2005; referred to there as Oph 1622−2405n and s,

[1] This paper includes data gathered with the 6.5 m Magellan Telescopes located at Las Campanas Observatory Chile.

[2] Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA 16802; kluhman@astro.psu.edu.
[3] Institute for Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822.
[4] Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawaii under Cooperative Agreement NCC 5-538 with the National Aeronautics and Space Administration, Office of Space Science, Planetary Astronomy Program.
[5] Department of Astronomy, The University of Texas, Austin, TX 78712.
[6] Steward Observatory, The University of Arizona, Tucson, AZ 85721.
[7] Spitzer Fellow.
[8] Current address: Department of Astronomy, University of Texas, Austin, TX 78712.
[9] Department of Astronomy, MS105-24, California Institute of Technology, Pasadena, CA 91125.
[10] SOFIA-USRA, NASA Ames Research Center, MS N211-3, Moffett Field, CA 94035.

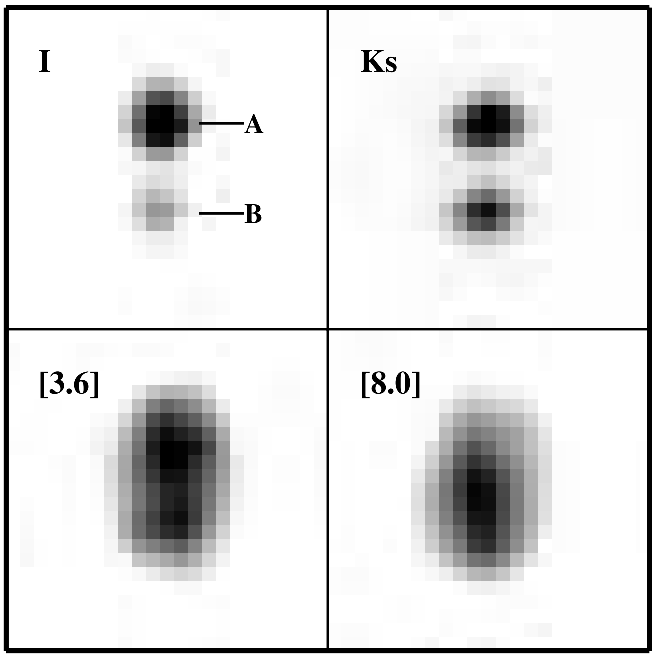

FIG. 1.—Discovery images of Oph 1622−2405A and B at I, K_s, 3.6 and 8.0 μm (Allers 2005). The size of each image is $7'' \times 7''$. North is up and east is left in these images.

respectively) are shown in Figure 1. The astrometry and photometry measured by Allers (2005) for this pair are provided in Table 1. Allers et al. (2006) described the collection and reduction of the larger imaging survey from which these images are taken. Close et al. (2007) measured near-IR colors for Oph 1622−2405A and B as well. Their colors differed significantly from those of field M and L dwarfs, which they attributed to low surface gravity. However, a color difference of that kind is not present in previous data for young late-M objects (e.g., Luhman 1999; Briceño et al. 2002), and the colors that we measure for Oph 1622−2405A and B are similar to those of both dwarfs and pre–main-sequence sources.

On the nights of 2006 August 17 and 18, we performed optical spectroscopy on Oph 1622−2405A and B, respectively, with the Low Dispersion Survey Spectrograph (LDSS-3) on the Magellan II Telescope and a 0.85″ slit. This configuration resulted in a spectral resolution of 5.8 Å at 8000 Å and a wavelength coverage of 5800–11000 Å. For each component of the binary, we obtained one 20 minute exposure with the slit aligned at the parallactic angle. After bias subtraction and flat-fielding, the spectra were extracted and calibrated in wavelength with arc lamp data. The spectra were then corrected for the sensitivity functions of the detectors, which were measured from observations of spectrophotometric standard stars. For comparison to Oph 1622−2405 in § 3.2, we will make use of a spectrum of the eclipsing binary brown dwarf 2M 0535-0546 (Stassun et al. 2006) that was obtained with LDSS-3 on 2006 February 10 and spectra of GL 1111 (M6.5 V) and LHS 2243 (M8 V) that were obtained with the Blue Channel spectrograph at the MMT on 2004 December 11 and 12, respectively. The LDSS-3 configuration for 2M 0535-0546 was the same as for Oph 1622−2405. The spectra of GL 1111 and LHS 2243 from Blue Channel have a resolution of 2.6 Å at 8000 Å and a wavelength coverage of 6300–8900 Å.

We obtained near-IR spectra of Oph 1622−2405A and B with the spectrometer SpeX (Rayner et al. 2003) at the NASA Infrared Telescope Facility (IRTF) on the nights of 2006 June 22 and 24. The instrument was operated in the SXD mode with a 0.5″ slit, producing a wavelength coverage of 0.8–2.5 μm and a resolving power of $R = 1200$. With the slit rotated to encompass both components of the pair, we obtained ten 2 minute exposures during sequences of dithers between two positions on the slit on each night. For comparison purposes, we also make use of a spectrum of the Taurus member CFHT 4 that was obtained on the night of 2006 January 4 with the same instrument configuration as used for Oph 1622−2405, except with a 0.3″ slit ($R = 2000$). These SpeX data were reduced with the SpeXTool package (Cushing et al. 2004) and corrected for telluric absorption (Vacca et al. 2003).

3. ANALYSIS

3.1. *Spectral Classification*

Spectral types of late-M dwarfs and giants are defined at red optical wavelengths (Kirkpatrick et al. 1991). Averages of optical spectra of standard dwarfs and giants agree well with data for late-M pre–main-sequence objects (Luhman et al. 1997, 1998; Luhman 1999) and are the basis of most of the published optical spectral types for low-mass members of nearby star-forming regions (e.g., Briceño et al. 2002; Luhman et al. 2003b; Luhman 2004a, 2006). We have applied this classification scheme to our optical spectra of Oph 1622−2405A and B, arriving at spectral types of M7.25 ± 0.25 and M8.75 ± 0.25, respectively. If we use dwarfs alone to classify our spectra, as done for this binary by Jayawardhana & Ivanov (2006b), then we derive nearly the same spectral types, namely M7.5 and M9. Figures 2 and 3 show comparisons of Oph 1622−2405A and B to these best-matching standards. The averages of dwarfs and giants match the target spectra more closely than dwarfs alone, in agreement with previous work (e.g., Luhman 1999). Thus, we adopt the types based on the comparisons to averages of dwarf and giant standards. By doing so, our classifications can be reliably compared to types of most known young late-type objects, which have been measured in the same way.

In Figure 2, we compare the spectrum of Oph 1622−2405A to data for the composite of the young eclipsing binary 2M 0535-0546 (§ 2) and the primary in the young wide binary 2M 1101-7732 (Luhman 2004b). This comparison demonstrates that Oph 1622−2405A is slightly later than 2M 0535-0546A+B (which we classify as M6.75) and has the same spectral type as 2M 1101-7732A (M7.25; Luhman 2004b). Meanwhile, Oph 1622−2405B is slightly later than 2M 1101-7732B (M8.25; Luhman 2004b) based on the comparison of their spectra in Figure 3.

TABLE 1
ASTROMETRY AND PHOTOMETRY FOR OPH 1622−2405

Component	α (J2000.0)	δ (J2000.0)	I	J	H	K_s	[3.6]
A	16 22 25.2	−24 05 13.7	17.78 ± 0.10	14.53 ± 0.03	14.01 ± 0.03	13.55 ± 0.03	13.02 ± 0.11
B	16 22 25.2	−24 05 15.6	18.98 ± 0.10	15.24 ± 0.03	14.64 ± 0.03	14.03 ± 0.03	13.22 ± 0.11

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

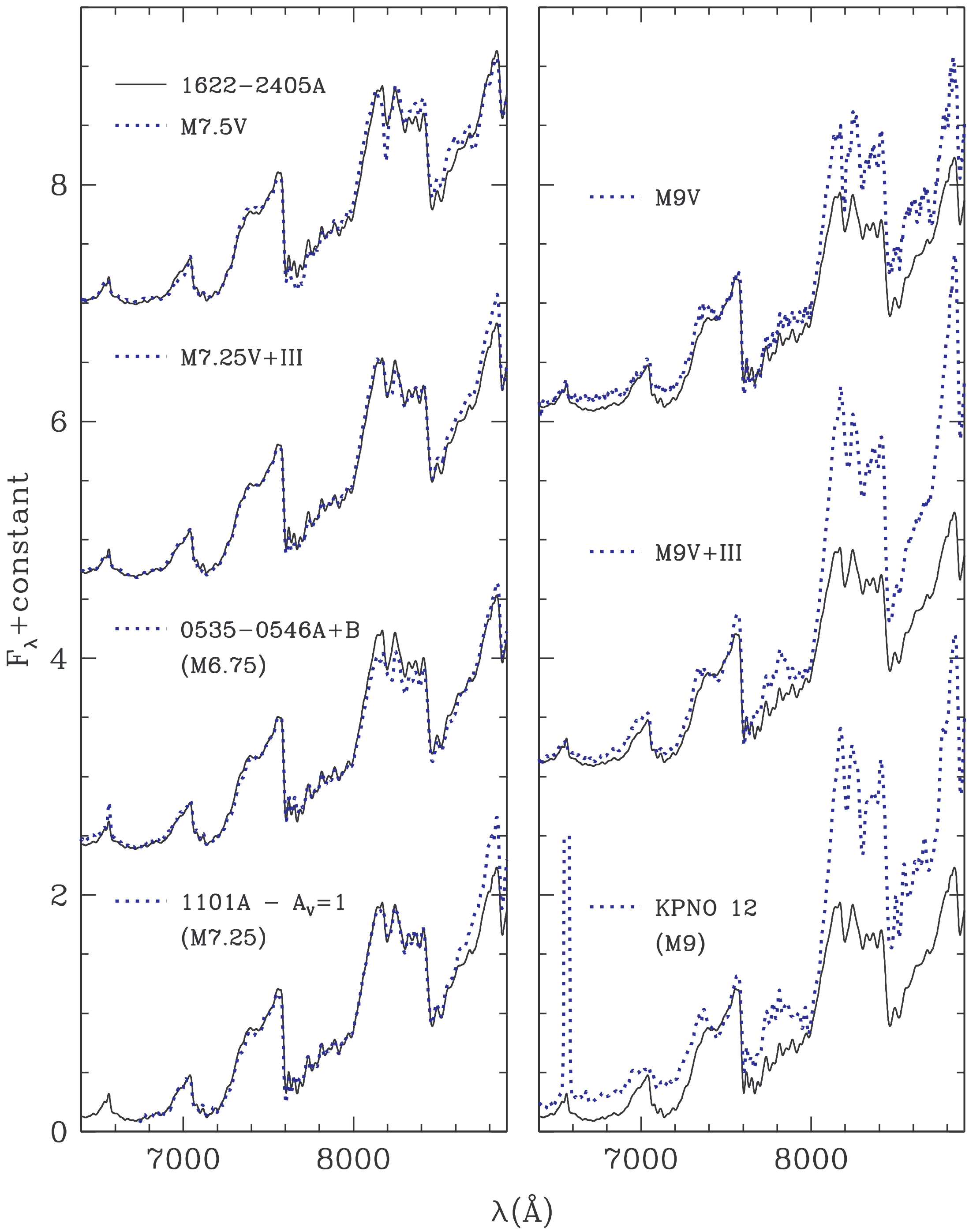

Fig. 2.—Optical spectrum of Oph 1622−2405A (*solid lines*) and seven comparison spectra (*dotted lines*). If dwarf standards are used to classify this object, then M7.5 V provides the best match. When we instead use averages of dwarfs and giants as standards, we derive a spectral type of M7.25. Oph 1622−2405A is slightly later than the composite spectrum of the eclipsing binary 2M 0535-0546, whose components have dynamical masses of 0.034 and 0.054 $M_\odot$ (Stassun et al. 2006). The spectrum of Oph 1622−2405A agrees well with the primary in the young binary 2M 1101-7732 (M7.25; Luhman 2004b). Although Jayawardhana & Ivanov (2006a) and Close et al. (2007) each reported a spectral type of M9 for Oph 1622−2405A, its spectrum differs significantly from those of M9 V, M9 V+M9 III, and the M9 Taurus member KPNO 12 (Luhman et al. 2003a). The data are displayed at a resolution of 18 Å and are normalized at 7500 Å.

Our optical spectral types of M7.25 ± 0.25 and M8.75 ± 0.25 for Oph 1622−2405A and B are significantly earlier than the optical types of M9 and M9.5-L0 from Jayawardhana & Ivanov (2006a, 2006b). This is true even if we use dwarf standards, as done in those studies. As shown in Figure 2, the spectrum of Oph 1622−2405A is poorly matched by both M9 V and M9 V+M9 III, as well as the M9 Taurus member KPNO 12 (Luhman et al. 2003a). Similarly, the spectrum of Oph 1622−2405B is earlier than KPNO 4 (Fig. 3), which is the prototypical pre–main-sequence representative of the M9.5 spectral class (Briceño et al. 2002). Oph 1622−2405B also differs significantly from M9.5 V and the young L0 object 2MASS 01415823-4633574 (hereafter 2M 0141-4633; Kirkpatrick et al. 2006). For instance, a defining characteristic of the transition from M to L types for dwarfs is the disappearance of TiO absorption at 7000–7200 Å (Kirkpatrick et al. 1999), and yet the TiO in Oph 1622−2405B is strong, indicating that a dwarf-based spectral type of M9.5-L0 is not appropriate. Our results for Oph 1622−2405A and B are similar to

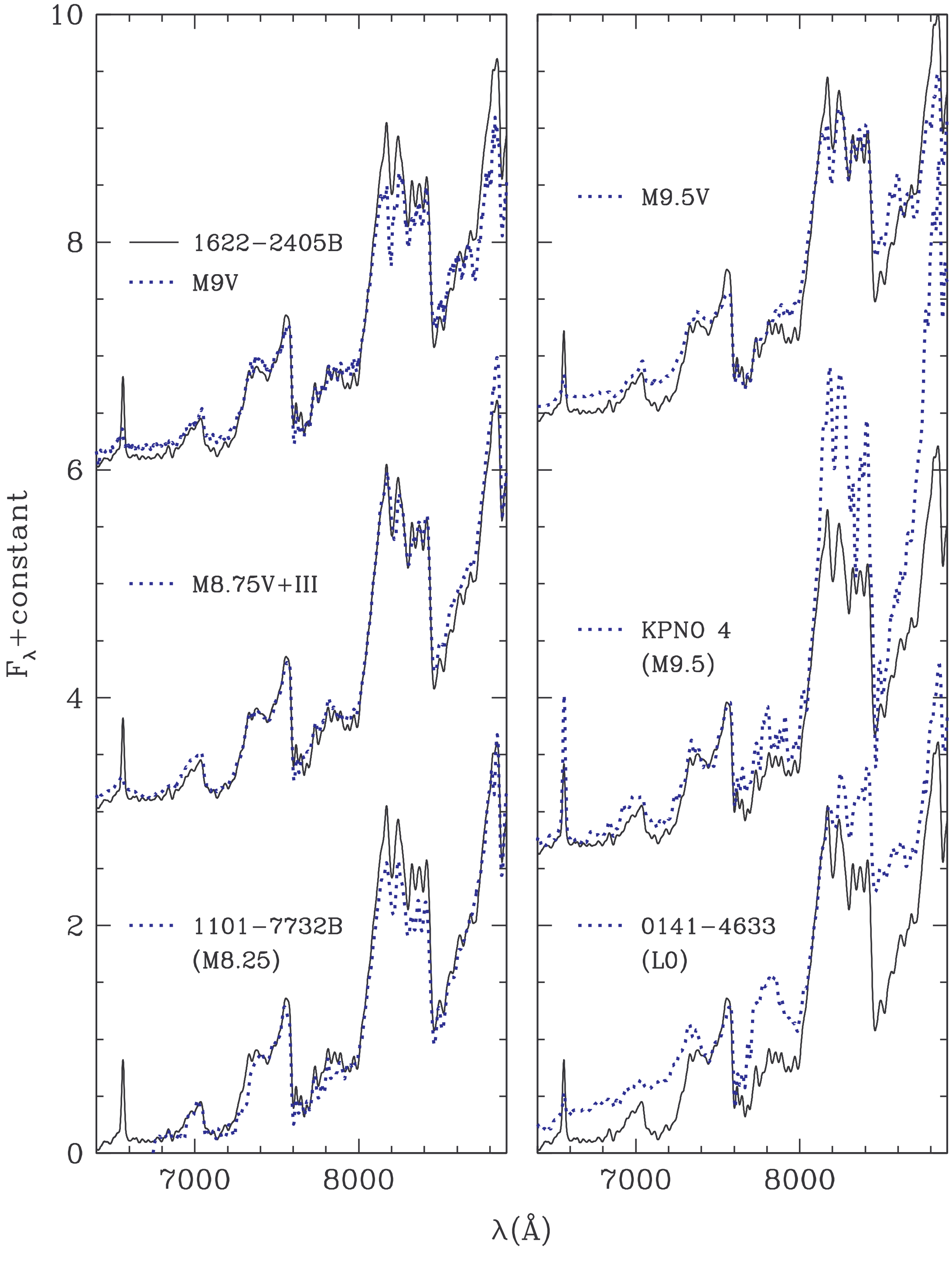

Fig. 3.—Optical spectrum of Oph 1622−2405B (*solid lines*) and six comparison spectra (*dotted lines*). If dwarf standards are used to classify Oph 1622−2405B, M9 V provides the best match. When we instead use averages of dwarfs and giants as standards, we derive a spectral type of M8.75. The average of the dwarf and giant agrees better with the spectrum of Oph 1622−2405B than the dwarf, as expected for a pre–main-sequence object of this kind (Luhman 1999). The spectrum of Oph 1622−2405B is later than the secondary in the young binary 2M 1101-7732 (M8.25; Luhman 2004b). Although Jayawardhana & Ivanov (2006b) and Close et al. (2007) reported spectral types of M9.5-L0 and M9.5 ± 0.5 for Oph 1622−2405B, respectively, its spectrum differs significantly from those of M9.5 V, the M9.5 Taurus member KPNO 4 (Briceño et al. 2002), and the young L0 object 2M 0141-4633 (Kirkpatrick et al. 2006). The data are displayed at a resolution of 18 Å and are normalized at 7500 Å.

those of Allen et al. (2007) for another object classified by Jayawardhana & Ivanov (2006a), 2M 1541-3345, which is a disk-bearing source in the vicinity of the Lupus clouds (Allers 2005; Allers et al. 2006). Jayawardhana & Ivanov (2006a) reported a spectral type of M8 for this object, while Allen et al. (2007) classified it as M5.75 ± 0.25 with spectra and methods like those used in this work.

We now compare our optical classifications of Oph 1622−2405A and B to previous near-IR observations. Our optical types of M7.25 ± 0.25 and M8.75 ± 0.25 for Oph 1622−2405A and B are consistent with the IR types of M7.5 ± 1 and M8 ± 1 from Allers (2005) and M7 ± 1 and M8 ± 1 from Allers et al. (2007), which were measured by comparison to young objects that have been optically classified with the same methods employed in this

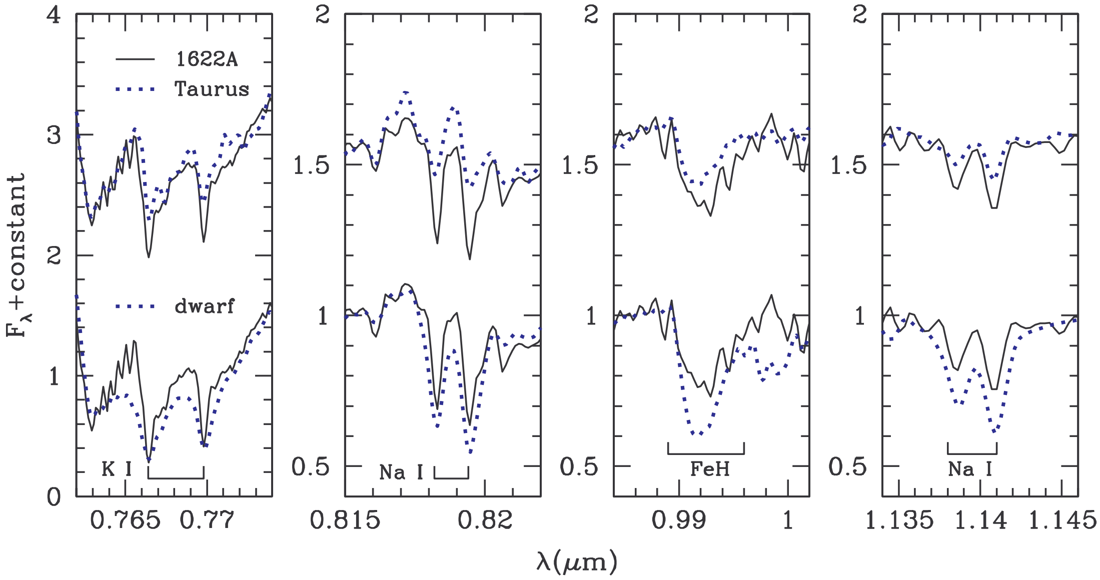

FIG. 4.—Gravity-sensitive absorption lines for Oph 1622−2405A (*solid lines*), a Taurus member ($\tau \sim 1$ Myr, *upper dotted lines*), and a field dwarf ($\tau > 1$ Gyr, *lower dotted lines*).

work. Brandeker et al. (2006) and Close et al. (2007) also presented near-IR spectra for Oph 1622−2405A, and B. Brandeker et al. (2006) did not compare their spectra to data for classification standards and thus did not measure spectral types. Close et al. (2007) found that Oph 1622−2405B exhibited similar IR spectral features as the young L0 source 2M J0141−4633 and thus classified the former as M9.5 ± 0.5. Because the spectral features of the primary indicated a slightly earlier type, they classified it as M9 ± 0.5. However, given that Close et al. (2007) did not present a comparison of Oph 1622−2405 to earlier types, it is unclear if earlier types would have provided better or worse matches to their data. In fact, as shown in Figure 3, our optical spectrum of Oph 1622−2405B is very different from the spectrum of 2M J0141−4633 from Kirkpatrick et al. (2006), demonstrating that they do not have the same optical spectral types.

Brandeker et al. (2006) and Close et al. (2007) estimated effective temperatures and surface gravities by comparing their data to synthetic spectra. However, because of known deficiencies in theoretical spectra of late-type objects (Leggett et al. 2001), temperature and gravity estimates of this kind are subject to systematic errors, and thus the accuracies of these estimates are unknown. In addition, the temperature and gravity estimates from those studies cannot be reliably compared to those of other young late-type objects unless the latter are derived with the same spectral features, model spectra, and fitting procedures.

3.2. *Age*

Allers (2005) and Allers et al. (2007) determined that the components of Oph 1622−2405 are pre–main-sequence objects rather than field dwarfs by performing low-resolution near-IR spectroscopy and detecting the presence of triangular *H*-band continua (Lucas et al. 2001). This spectral characteristic is present during most of the pre–main-sequence evolution of late-type objects, thus constraining the age of Oph 1622−2405 to be $\tau \lesssim 100$ Myr (Kirkpatrick et al. 2006; Allers et al. 2007). To further constrain the age of this system, we examine additional gravity-sensitive absorption lines in our higher resolution optical and near-IR spectra, namely K I, Na I, and FeH (Martín et al. 1996; Luhman et al. 1998; Gorlova et al. 2003; McGovern et al. 2004).

In this analysis, we consider only the primary because its data exhibit a better signal-to-noise ratio. For comparison to Oph 1622−2405A, we select representatives of three distinct luminosity classes and ages: members of the Taurus star-forming region ($\tau \sim 1$ Myr; Briceño et al. 2002; Luhman et al. 2003a), members of the Upper Scorpius OB association ($\tau \sim 5$ Myr; Preibisch & Mamajek 2006), and field dwarfs ($\tau > 1$ Gyr). We require that these objects have spectral types that are within 0.5 subclass of the spectral type of the primary so that our comparison is sensitive to variations in surface gravity alone. For Taurus we use the optical spectrum of 2MASS 04484189+1703374 (M7; Luhman 2006) from Luhman (2006) and our IR spectrum of CFHT 4 (M7; Briceño et al. 2002). Field dwarfs are represented by an average of our optical spectra of GL 1111 (M6.5 V; Henry et al. 1994) and LHS 2243 (M8 V; Kirkpatrick et al. 1995), and the IR spectrum of vB 8 (M7; Kirkpatrick et al. 1991) from Cushing et al. (2005). For Upper Sco, we use the *J*-band spectrum of U Sco CTIO 128 (M7; Ardila et al. 2000) from Slesnick et al. (2004). To enable a reliable comparison of absorption line strengths, spectra for a given wavelength range have been smoothed to a common spectral resolution. Although optical spectra for Upper Sco are available from Slesnick et al. (2006), we do not include them in this comparison because they have significantly lower spectra resolution that the other optical data we are examining, and we prefer to make these comparisons at the highest possible resolution.

In Figures 4 and 5, we compare the spectra for Taurus, Upper Sco, and field dwarfs to the spectrum of Oph 1622−2405A for wavelength ranges encompassing K I, Na I, and FeH. For all of these transitions, Oph 1622−2405A exhibits stronger lines than the Taurus members and weaker lines than the field dwarfs, indicating that it is above the main sequence ($\tau \lesssim 100$ Myr), but older than Taurus ($\tau > 1$ Myr). For the subset of comparisons in which Upper Sco is represented, the line strengths are similar between Oph 1622−2405A and the Upper Sco member. If we degrade the optical spectrum of Oph 1622−2405A to the lower spectral resolution of optical data in Upper Sco from Slesnick et al. (2006) we also find similar line strengths for the optical transitions of Na I and K I. Thus, the gravity-sensitive lines in the spectra of Oph 1622−2405A suggest an age similar to that

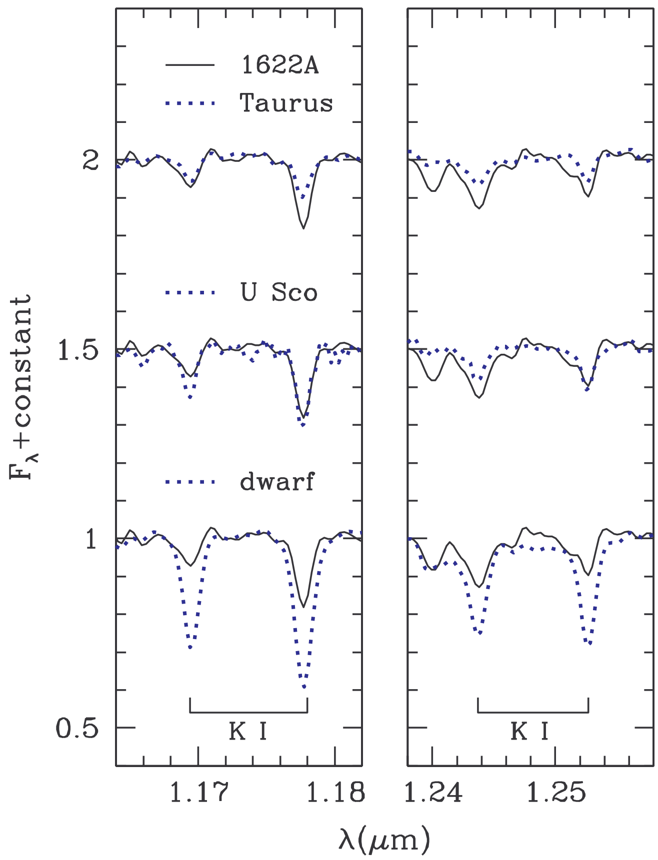

Fig. 5.—Gravity-sensitive absorption lines for Oph 1622−2405A (*solid lines*), a Taurus member ($\tau \sim 1$ Myr, *upper dotted lines*), an Upper Sco member ($\tau \sim 5$ Myr, *middle dotted lines*), and a field dwarf ($\tau > 1$ Gyr, *lower dotted lines*). The data in this diagram and in Fig. 4 indicate that Oph 1622−2405A is a pre–main-sequence source with an age of ~5 Myr.

of Upper Sco ($\tau \sim 5$ Myr) with an upper limit that is undetermined, but probably no more than a few tens of millions of years.

Using their near-IR spectra of Oph 1622−2405A and B, Brandeker et al. (2006) compared the equivalent widths of gravity-sensitive lines between Oph 1622−2405 and field dwarfs, demonstrating that the binary's components have lower gravities, and hence younger ages than dwarfs, which is consistent with the results in this work, Allers (2005), Allers et al. (2007), and Close et al. (2007). However, their analysis did not further refine the age of the system, and they did not claim to accurately measure the gravities and ages of Oph 1622−2405A and B and instead assumed membership in Ophiuchus. On the other hand, Close et al. (2007) constrained the gravity of Oph 1622−2405A and B more tightly by comparing their data to KPNO 4 ($\tau \sim 1$ Myr) and σ Ori 51 ($\tau \sim 5$ Myr). This comparison indicated that Oph 1622−2405A and B are older than KPNO 4 and similar in age to σ Ori 51, which is in agreement with the age constraints that we have derived in this section.

3.3. *Membership*

The analysis of gravity-sensitive lines in § 3.2 demonstrated that Oph 1622−2405A is older than Taurus ($\tau \sim 1$ Myr), which in turn is older than the stellar population within the Ophiuchus cloud core ($\tau < 1$ Myr; Luhman & Rieke 1999). Thus, Oph 1622−2405 is not a member of the current generation of stars forming within the Ophiuchus cloud, which is consistent with the low extinction of this binary ($A_V < 1$) and its large angular distance from the cloud core ($\theta \sim 0.5''$). Instead, Oph 1622−2405 probably is part of an older population of stars in the Sco-Cen complex, which contains several neighboring and overlapping generations of stars with ages from <1 to 20 Myr (Preibisch & Mamajek 2006). For instance, Oph 1622−2405 is within the area encompassed by known members of Upper Sco (Slesnick et al. 2006; Preibisch & Mamajek 2006) and is near a population of exposed young stars distributed across the front of the Ophiuchus cloud, which is coeval with Upper Sco and may be an extension of it (Wilking et al. 2005).

TABLE 2

Properties of Oph 1622−2405

Component	Spectral Type	$T_{\rm eff}$[a] (K)	$\log(L/L_\odot)$[b]	Mass ($M_\odot$)
A.......................	M7.25 ± 0.25	2838	−2.41 ± 0.13	0.055 ± 0.01
B.......................	M8.75 ± 0.25	2478	−2.63 ± 0.13	$0.019^{+0.01}_{-0.005}$

[a] Temperature scale from Luhman et al. (2003b).
[b] Based on an assumed distance of 145 ± 20 pc.

Although we cannot definitively identify the origin of Oph 1622−2405 nor measure its distance, membership in Upper Sco is likely based on its location and surface gravity diagnostics. Indeed, this evidence of membership in Upper Sco is the same as for previously reported late-type members (Martín et al. 2004; Slesnick et al. 2006). Therefore, for the purpose of estimating their luminosities, we assign to Oph 1622−2405A and B the distance of Upper Sco, which extends from 125 to 165 pc (Preibisch & Mamajek 2006). Based on the comparison of the optical spectra of Oph 1622−2405A and B to spectra of other young late-type objects in § 3.1, we find that the extinction of each component is $A_V < 1$. Therefore, we adopt $A_V = 0.5 \pm 0.5$ for measuring their luminosities. The remaining details of the luminosity estimates are provided by Allers et al. (2006). Our luminosity measurements for Oph 1622−2405A and B are listed in Table 2.

To examine the ages implied by their luminosities, we plot Oph 1622−2405A and B on the H-R diagram in Figure 6 with the evolutionary models of Baraffe et al. (1998) and Chabrier et al. (2000). We have converted our optical spectral types to effective temperatures with a temperature scale that is compatible with these models for young objects (Luhman et al. 2003b). The data and models in Figure 6 imply ages of 10–30 Myr for the primary and 1–20 Myr for the secondary. Thus, these results are consistent with coevality for the two objects, which is expected for a binary system. These ages are somewhat older than the canonical value of 5 Myr that is usually quoted for Upper Sco, but the age of a young population is sensitive to how it is defined, the mass range of objects considered, and the choice of models. To reliably compare the inferred ages of Oph 1622−2405A and B to those of Upper Sco members, the luminosities and temperatures of this binary should be compared directly to those of late-type members of Upper Sco. We do this by including in Figure 6 the late-type members of Upper Sco from Slesnick et al. (2006). The lower limits of the sequence in temperature and luminosity are reflections of the detection limits of the survey from Slesnick et al. (2006). An extension of the sequence below these limits in a manner that is parallel to the theoretical isochrones would encompass both components of Oph 1622−2405. In other words, the model ages of the more massive members of the Upper Sco sequence from Slesnick et al. (2006) are consistent with the model ages of Oph 1622−2405A and B. Similarly, the binary components fall within the sequence of low-mass Upper Sco members in the color-magnitude diagram from Martín et al. (2004).

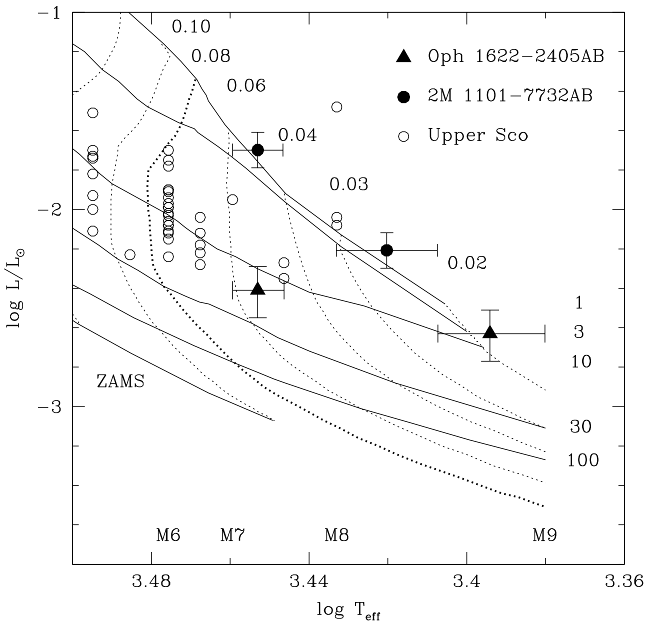

FIG. 6.—H-R diagram for Oph 1622−2405A and B (*filled circles*; Table 2; Allers 2005), 2M 1101-7732A and B (*triangles*; Luhman 2004b), and members of Upper Sco (*circles*; Slesnick et al. 2006) shown with the theoretical evolutionary models of Baraffe et al. (1998; $M/M_\odot > 0.1$) and Chabrier et al. (2000; $M/M_\odot \leq 0.1$), where the mass tracks (*dotted lines*) and isochrones (*solid lines*) are labeled in units of $M_\odot$ and Myr, respectively. According to this diagram, Oph 1622−2405A and B have masses that are similar to those of 2M 1101-7732A and B. In addition, the positions of Oph 1622−2405A and B are consistent with an extension of the Upper Sco sequence to lower masses.

3.4. *Mass*

In addition to ages, the evolutionary models in Figure 6 also provide estimates of masses, implying values of 0.055 ± 0.01 and $0.019^{+0.01}_{-0.005}$ $M_\odot$ for Oph 1622−2405A and B, respectively. The quoted uncertainties reflect only the uncertainties in spectral types and luminosities. Additional systematic errors could be introduced by the adopted temperature scale and evolutionary models. However, the sizes of these systematic errors are probably not large, as demonstrated by various observational tests (Luhman et al. 2003b; Luhman & Potter 2006). The mass estimated for Oph 1622−2405A by Allers (2005) is similar to our value, while her estimate for the secondary was twice our value because of the earlier spectral type that she derived. Meanwhile, our estimates for Oph 1622−2405A and B are significantly higher than the masses of 0.013 and 0.007 $M_\odot$ from Jayawardhana & Ivanov (2006b). Our estimate for the primary is also much higher than the value of 0.017 $M_\odot$ from Close et al. (2007), while our mass for the secondary is only slightly higher than their mass of 0.014 $M_\odot$. The validity of higher estimates is supported by the fact that Oph 1622−2405A is only slightly cooler than the composite of the eclipsing binary brown dwarf 2M 0535-0546A+B (Fig. 2) and thus should have a comparable mass ($M = 0.054$ and 0.034 $M_\odot$; Stassun et al. 2006).

The spectral types, temperatures, luminosities, and masses of Oph 1622−2405A and B produced by our analysis are compiled in Table 2.

4. CONCLUSIONS

Using optical spectroscopy, we have measured spectral types for the young binary Oph 1622−2405 that are significantly earlier than those reported by Jayawardhana & Ivanov (2006a, 2006b) and Close et al. (2007). As a result, our mass estimates for these objects ($M = 0.055$ and 0.019 $M_\odot$) are higher than those from Jayawardhana & Ivanov (2006a, 2006b; $M = 0.013$ and 0.007 $M_\odot$) and Close et al. (2007; $M = 0.017$ and 0.014 $M_\odot$) and are above the range of planetary masses ($M \lesssim 0.015$ $M_\odot$; Marcy et al. 2005). Through a direct comparison of their spectra, we find that the primaries in Oph 1622−2405 and the young wide binary 2M 1101-7732 have the same spectral types, while Oph 1622−2405B is only slightly later than 2M 1101-7732B, which strongly indicates that these two binaries have similar masses. Our analysis of gravity-sensitive absorption lines in the spectra of Oph 1622−2405A have demonstrated that this system is too old to be a member of the Ophiuchus star-forming region ($\tau < 1$ Myr). Instead, the age constraints from those data combined with the position of Oph 1622−2405 on the H-R diagram are consistent with membership in Upper Sco ($\tau \sim 5$ Myr).[11] Additional observations (e.g., proper motions, radial velocities) are needed to better determine the origin and membership of this binary system. If the distance of Upper Sco is adopted for Oph 1622−2405, then the separation of 1.9″ for this binary corresponds to ~300 AU, making it the second young wide binary brown dwarf to be found. Thus, Oph 1622−2405 is very similar to 2M 1101-7732 in both mass and separation, but is somewhat older (5 Myr vs. 1 Myr). Given the advanced age of this system compared to most disk-bearing stars and brown dwarfs, the disk detected in Oph 1622−2405 by Allers et al. (2006) is a valuable laboratory for studying the evolution of brown dwarf disks.

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[11] Using the same spectral classification methods shown in this work, Allen et al. (2007) concluded that another object from Jayawardhana & Ivanov (2006a), 2M 1541-3345, is also earlier, older, and more massive than reported in that study.

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